Final disposal of toner waste in cement mortars

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Abstract- Based on a waste survey from the city of Bahia Blanca, generated by companies in the area, the possibility of placing them within a cement matrix was analyzed. One of the materials found is toner, obtained as waste from cartridges used in photocopiers, laser printers, faxes. The work aims to analyze the physical and mechanical properties of cement mortars with the incorporation of toner and compare them with a standard sample (without waste). Mixes were made with the incorporation of 2.5%, 5%, 10% and 15% of toner concerning the weight of the cement, to measure normal consistency, setting times and mechanical resistance in mortars employing standardized tests. At a later stage, it is intended to study their incorporation into concrete. Also, an analysis of leachate in the curing water was carried out after 56 days, looking for contaminating materials. The incorporation of toner did not produce significant changes in the final setting time, nor in the mechanical resistances. No heavy metals were found in the leachate. It is concluded that the incorporation of toner in cement mortars is a possible alternative for the final deposition of this waste without affecting the environment or producing significant changes in the properties of the mixture.

Keywords- waste, toner, cement mortars.

I. Introduction

Currently, there are different ways to manage the waste generated by the population. One of them is to use the waste in cement mixtures. In this paper, the behavior of mortar samples with the incorporation of toner, a waste obtained from printer and photocopier cartridges, was studied.

The electronics industry, at the demand of society, generates solid waste in quantity, called electronic waste, and there are processes to recover part of its components. These residues are formed by a variety of materials: metals such as iron, steel, aluminum, copper, some heavy metals, screen glass, and different plastics. The prevailing and practical process for removing valuable items from electronic waste is to throw them into an open fire, to remove the worthless plastic and metal, through combustion. The problem with this process is that it is harmful to the environment, because of the emission of toxic gases. To use the components of the electronic waste, a dismantling process is carried out. The equipment is separated into different parts such as metal frames, printed circuits, power supplies, plastics, and others.

The main problems in the recycling of electronic elements are their high content of toxic and polluting materials, and the complexity of the technologies to carry out an adequate separation. However, the inclusion of shredded electronic waste (plastics and glass properly separated from the contaminating components) in concrete as a partial replacement of the coarse aggregate has been studied [1, 2]. Among the most frequently generated computer consumables are ink and toner cartridges for printers, photocopiers and faxes. The growing global demand for ink production has led to a large accumulation of its waste and has become a threat to the environment. Using these residues in new materials can be a promising approach to ink waste management [3, 4].

Toner is a fine powder, mainly composed of carbon and iron, which due to electrostatic or magnetographic attraction, pressure and heat is fixed to the paper to print images or text. Among its main components are also chromium, copper, inorganic cyanides, acrylics, photographic developer and thermoplastic particles, which if not properly managed, would cause contamination when discarded. The composition and particle size turn the disposal of the quantities of waste toner into a serious problem. The fine toner particles (>10 µm) may remain suspended in the air for some period of time, which can cause the occurrence of certain negative health effects [5]. Usually, ink cartridges are thrown into the domestic waste circuit, without further controls and contaminating the sanitary landfills. Prior to any kind of recycling treatment, toner cartridges should be removed from printers. Approximately 10 % of toner powder remains in photocopiers [6]. It is considered that an empty and obsolete cartridge for printing still contains 25 grams of toner [7].

The possibility of waste toner powder recycling in concrete industry is poorly investigated. Some researchers have used powder recovered from toner printer cartridges as a viable pigment in concrete [8]. The use of this waste in the production of asphalt mixtures for flexible pavements has been reported with success [9, 10]. The toner powder used to make asphalt comes from recycled cartridges. This toner powder is homogenized and then agglomerated to produce a particle of 1 to 3 mm of diameter. During the agglomeration process, one or more additional materials can be added, such as recycled motor oil. The final product is used as a polymer-based additive to produce the asphalt with significant advantages of energy savings (the toner mixture is heated to a temperature 20 to 50ºC lower than normal asphalt, using less energy for its production), reduction of landfills (toner collection allows for a decrease in the number of cartridges that end up in landfills), reduction of crude oil used in roads (using printer toner in the asphalt mix reduces the amount of asphalt derived from crude oil), generating a high-strength product that reduces the formation of cracks in roads, minimizes maintenance costs and increases durability [11].

Furthermore, it was stated that by increasing the percentage of toner included up to 12%, the rheological properties of the asphalt binder were improved [12] and polymer modified binders showed an increase in viscosity [13]. This enhancement could be useful in cement mixtures.

The present paper is the first stage of a wider research plan that proposes the study of the incorporation of toner, waste extracted from cartridges, in cement mortars and concrete.

In this first stage, the influence of toner on some properties of cement pastes and mortars will be studied.

This topic is of interest from a scientific point of view since it contributes to the transformation of waste that exists in our country, developing sustainable technology and with fairly direct applications.

II. Materials And Methods

To produce cement pastes and mortars, demineralized water (for mixing and curing samples), cement from a factory in the province of Buenos Aires, identified as normal Portland CPN40 and as fine aggregate, natural quartzite sand was used.

The toner incorporated (Fig.1) in the mixtures was obtained from cartridges discarded at printing shops, and only black toner was used, in order to have the same chemical composition and it is also the most widely consumed color. It was incorporated into pastes and mortars, in four different concentrations: 2.5% ($T_{2.5}$), 5% (T_5), 10% (T_{10}) and 15% (T_{15}) of toner concerning the weight of the cement, to compare results with a reference sample, without the addition of the waste (T_0).

Fig. 1 Toner incorporated

In the first stage of the paper involving cement mixtures, the amount of water needed to reach pastes of normal consistency was evaluated according to IRAM Standard 1612 [14] with 500 grams of cement and the initial and final setting times were determined according to IRAM Standard 1619 [15]. A paste of normal consistency is defined as the paste in which the Tetmajer probe penetrates 10 ± 1 mm 30 seconds after being released, using the Vicat apparatus.

Then, mortars were proportioned with a water/cement ratio of 0.50 and 3 sets of 3 prismatic specimens of 4x4x16 cm were molded for each of the toner doses studied, according to the methodology indicated in the IRAM Standard 1622 [16] Mixes were made with 1350g of sand, 450g of cement, 225g of water and toner incorporated.

Flexural and compressive strength tests were carried out to evaluate the mechanical performance of cement mortars, according to IRAM Standard 1622, at the ages of 7, 28 and 56 days.

Since toner can be considered a hazardous waste, the mobility of contaminants was studied from a lixiviate analysis in the curing water after 56 days, by means of an Induced Plasma Atomic Emission Spectrometry (ICP-OES) performed with a simultaneous Shimadzu model 9000 equipment.

III. Results And Discussion

A. Normal Consistency Paste

During the mixing of the toner-based pastes, black bubbles were observed, produced by the effect of the incorporation of the residue in the cement mixtures.

Table 1 details the percentages of water required (expressed concerning the weight of the cement) to achieve pastes of normal consistency, in each of the mixtures studied in this work.

TABLE 1
TONER AND WATER CONCENTRATION IN THE MIXTURES

Sample	Toner Doses (%)	Water Quantity (%)
T_0	0	25,0
$T_{2,5}$	2,5	25,6
T_5	5	26,0
T_{10}	10	29,0
T_{15}	15	33,0

As the percentage of toner incorporated into the cement mixture increases, the amount of water required to achieve normal consistency pastes increases. This test only quantifies the plasticity of the cement paste, therefore it does not correlate with the water required to prepare a mortar or concrete with the same cement.

B. Setting Times

When a hydraulic binder is mixed with water to obtain a paste of normal consistency [17], it successively presents two different events that develop over time:

a) sudden increase in viscosity followed by a rise in temperature of the paste (beginning of setting), and

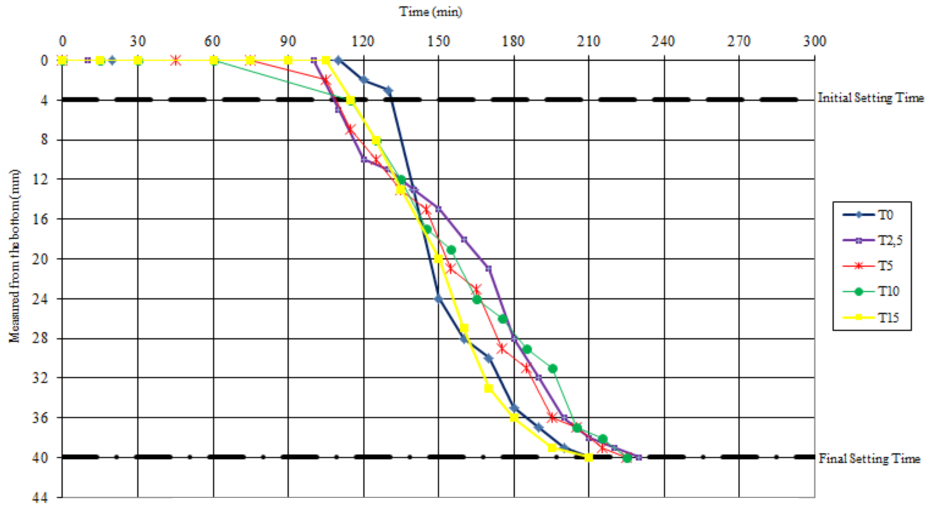

Fig. 2 Needle penetration test to establish the setting time.

b) progressive and regular transformation of the paste into a rigid block (end of setting).

TABLE 2
SETTING TIMES

Sample	Setting Times (min)	
	Initial	Final
T_0	131	210
$T_{2,5}$	108	230
T_5	109	225
T_{10}	115	225
T_{15}	115	210

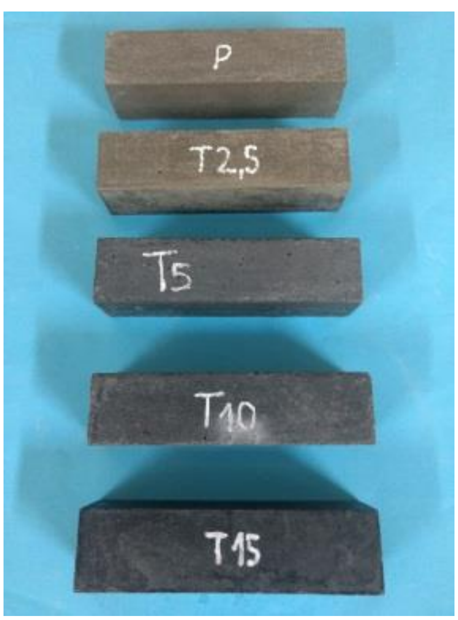

Fig. 3 Samples with different toner doses.

Fig. 2 shows the initial and final setting times of the pastes and Table 2 shows the phenomenon indicated for each dosage.

Fig. 2 and Table 2, show that the addition of toner brought forward the start of the setting and delayed the corresponding time values at the end of the setting, concerning the standard sample. The maximum difference in the initial and final setting time was presented by sample $T_{2,5\%}$ (18% and 9% respectively) when compared to the reference specimen.

From a practical point of view, these two variations do not have a significant influence that could affect their use in constructions.

C. Mechanical Strengths

The mortar bars molded were tested at 7, 28 and 56 days to determine maximum compressive and flexural strengths.

Fig. 3 shows the samples with different toner doses. As the percentage of toner incorporated into the cement mixture increases, the color of the samples is darker.

Fig. 4 shows the variation in compressive strength over time for the different doses used.

The compressive strength of the tested bars decreases as the addition of toner rises. For all ages studied, this loss is not much significant with additions of up to 5% of toner, while for higher doses, 10% and 15% of toner, the loss is in the order of 11% and 17% at 28 days and 15% and 20% at 56 days, respectively. It is similar to what happened in the flexural test.

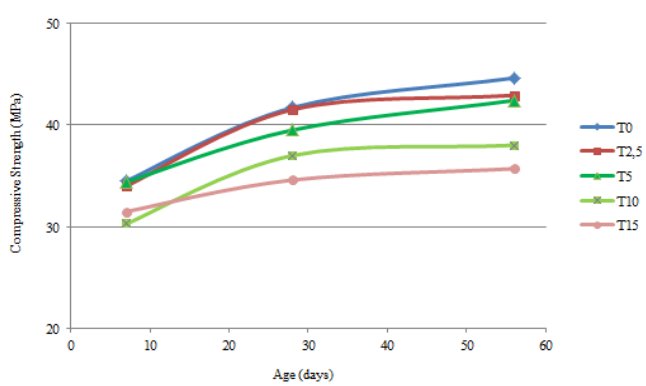

Fig. 4 Compressive Strength.

TABLE 3
ELEMENTS DETECTED IN THE SPECTROMETRY

Sample	Al (mg/l)	B (mg/l)	Ba (mg/l)	Ca (mg/l)	Cr (mg/l)	Cu (mg/l)	Fe (mg/l)
T_0	4,20	0,05	0,01	0,34	0,01	0,02	< 0,01
$T_{2,5}$	< 0,19	0,17	0,01	0,74	0,01	0,02	0,01
T_5	4,10	0,05	0,01	0,40	0,01	0,02	0,01
T_{10}	< 0,19	0,69	0,05	0,69	0,01	0,02	< 0,01
T_{15}	11,00	0,05	0,02	1,10	0,02	0,02	0,03

TABLE 4
ELEMENTS DETECTED IN THE SPECTROMETRY TEST

Sample	K (mg/l)	Li (mg/l)	Mg (mg/l)	Na (mg/l)	S (mg/l)	Si (mg/l)	Sr (mg/l)	Zn (mg/l)
T_0	94	0,13	0,02	48	11	20	0,01	< 0,01
$T_{2,5}$	72	0,07	0,05	28	9	18	0,02	< 0,01
T_5	99	0,10	0,02	43	7,2	13	0,01	< 0,01
T_{10}	100	0,09	0,05	45	3,6	15	0,06	< 0,01
T_{15}	88	0,17	0,05	79	11	23	0,03	0,08

D. Leachate

Leachate analysis in the residual liquid of the curing water after 56 days was performed, using induced plasma Atomic Emission Spectrometry. Tables 3 and 4 show the results.

On a 71-element scan in qualitative mode by Induced Plasma Atomic Emission Spectrometry (ICP-OES), only significant emission signals were detected for aluminum, calcium, sodium, sulfur, and silica. It can be attributed to the fact that the elements mentioned are part of the chemical composition of the cement and not to the addition of the toner.

All values detected by the test are less than the permissible limits established by Provincial Law [18] for rainwater discharges.

IV. CONCLUSIONS

Variations in setting times generated by the incorporation of the residue in cement mixtures are not relevant.

As far as mechanical properties are concerned, it can be affirmed that with a 5% incorporation of toner the strength loss is not very significant. The greatest decrease in resistance recorded was at 56 days of age, for the sample with the maximum toner content tested.

No contaminants in the curing water that exceeded the permitted values were recorded. Therefore, it is inferred that the incorporation of toner does not generate dangerous leachate.

From these tests, it can be concluded that the incorporation of toner in percentages less than and equal to 15% in cement mixtures is a possible alternative for the final disposal of this waste without affecting the environment.

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